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BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

INVESTIGATION OF ELECTRICAL EQUIPMENT, SAFETY LAMPS, AND GAS DETECTORS FOR SAFETY

BY

L. C. ILSLEY

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

INVESTIGATION OF ELECTRICAL EQUIPMENT, SAFETY LAMPS, AND GAS DETECTORS FOR SAFETY[1]

By L. C. Ilsley[2]

INTRODUCTION

Investigations for safety of electrically operated mine equipment, safety lamps, and gas detectors are made at the Pittsburgh Experiment Station in accordance with published regulations termed "schedules." These schedules are revised from time to time, not only to keep in step with the progress of the industry, but also to permit as much freedom of design as possible without lowering standards of safety.

The following schedules covering electrical equipment, safety lamps, and gas detectors are now active:

Schedule 2D. Explosion-Proof Mine Equipment. Requirements for Approval of of Storage-Battery Locomotives and Power Trucks, Junction Boxes, and Electric Motor-Driven Equipment.

Schedule 6C. Permissible Electric Cap Lamps. Procedure in Testing, Fees Charged, and Requirements for Approval.

Schedule 7C. Flame Safety Lamps; Requirements for Permissibility, Tests Made, and Fees Charged.

Schedule 8C. Portable Methane Detectors; Requirements for Permissibility, Tests Made, and Fees Charged.

Schedule 9B. Permissible Telephones and Signaling Devices; Requirements for Permissibility, Tests Made, and Fees Charged.

Schedule 10C. Electric Mine Lamps, Other Than Cap Lamps; Requirements for Permissibility, Tests Made, and Fees Charged.

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2/ Supervising engineer, Electrical-Mechanical Section, Mining Division, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

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Schedule 12B. Single-Shot Blasting Units; Requirements for Permissibility, Tests Made, and Fees Charged.

Schedule 16A. Multiple-Shot Blasting Units; Requirements for Permissibility, Tests Made, and Fees Charged.

Under these schedules it is possible to have nearly every type of equipment used at or near the face of active mine workings investigated for its liability to ignite mine gas or coal dust or a combination of gas and dust.

The investigation of mine equipment under schedule requirements was begun in 1913 and has been continuous since then. There has been a marked increase in the use of electrical equipment, especially of the explosion-proof type, during the last 15 years, and interest in all lines of permissible equipment is evident.

INVESTIGATIONS UNDER SCHEDULE 2D

Under Schedule 2D, electrical accessories for storage-battery locomotives and storage-battery-type power trucks, cutting machines, loading machines, room hoists, drills, air compressors, rock-dusting machines, and pumps are investigated.

Details of Investigations

Such investigations include (A) a detailed inspection; (B) tests in explosive mixtures; and (C) a final inspection of the accessories in the completely assembled unit.

(A) Detailed Inspection

The detailed inspection is an important part of the investigation and usually requires more time than the tests in explosive atmospheres. The following points are considered:

1. A check of parts against drawings as to material, dimensions, and position, making notations for correction of discrepancies between the drawings and the parts checked.

2. Measurement of flanges, bearings, and other possible flame paths.

3. Examination for unnecessary through-holes.

4. Examination for adequacy of electrical clearances or insulation between live parts and ground.

5. Examination for adequacy and security of fastenings, including lead entrances and inspection covers.

6. Interconnecting wiring and trailing cable connections.

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Figure 1.—Motor-testing gallery.

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(B) Tests in Explosive Mixtures

Electrical accessories are tested in the large testing gallery of which figure 1 shows a general view. This gallery is 10 feet in diameter and 4-1/2 feet in height, with a volume of approximately 400 cubic feet (11.3 cubic meters). Pittsburgh natural gas, which contains a high percentage of methane, is used for obtaining the explosive mixture. Usually not less than 20 tests are made on a given compartment, and complicated enclosures often are subjected to 50 or more tests.

The mixture within the accessory housing is ignited by a spark plug or other suitable means, and a record of pressures developed is taken. The point of ignition is varied to determine the condition that gives the greatest pressure. For some of the tests bituminous coal dust is introduced into casings, and the effects are noted.

The explosion tests of an enclosure shall not result in (a) discharge of flame from any joint or opening; (b) ignition of surrounding explosive mixtures; (c) development of dangerous afterburning; or (d) excessive pressures. (Indicated pressures of 150 pounds per square inch gage or over are considered as being excessive.) A compartment will be rejected if it fails to meet any one of the four above conditions.

(C) Final Inspection

In addition to the detailed inspections and the tests, inspection of the machine as a whole is made at the close of the investigation to ascertain whether the assembly of motors, controllers, rheostats, and other parts in relation to each other has any unsafe features, special note being made of the position and guarding of wiring between these parts. The drawings and specifications also are checked to see that they have been corrected to show all changes made in parts during the investigation. Manufacturers must notify the electrical engineer at the Pittsburgh Experiment Station when the first of a given design of machine built for approval will be completed in order that a Bureau engineer may have an opportunity to examine it when such examination is considered necessary. Examinations are preferably made at the factory where cranes and other facilities make it possible to inspect a machine more thoroughly and quickly than would be possible elsewhere.

A label is used to identify all equipment that has passed the Bureau's schedule requirements. This label is only placed on complete units because an approval not only includes all the accessories but also all the wiring between them. Proper installation of the wiring between compartments is considered very important in the safety of the unit as a whole.

This procedure seems very necessary in this country where there is no centralized authority for coal mines (each of 30 different States mining coal has its own safety regulations, and only one of these has a State electrical inspector); therefore, it is not considered a safe procedure to approve individual accessories and leave to the local mine management the responsibility of correctly wiring and assembling the separate parts.

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With the approval letter the manufacturer receives a photograph of a design of "approval label." This label bears the seal of the Bureau of Mines, United States Department of the Interior, the approval number, the name of the class of equipment to which the equipment belongs, and the name of the manufacturer. When necessary, an appropriate statement giving the precautions to be observed in maintaining the equipment in an approved condition are added.

The manufacturer has this design reproduced either as a separate plate or by stamping or molding it in some suitable place on each permissible unit. The size and mounting of the approval label must be satisfactory to the Bureau and a sample of the label adopted is sent to the Bureau for record.

Changes in Design Subsequent to Approval

All approvals are granted with the understanding that the manufacturer will make his machine according to the specifications which he has submitted to the Bureau and which have been considered and recorded in the approval. Therefore, if he desires to make any change in the design of the machine, he must first obtain the Bureau's authorization for the change. When the modified part has been found to comply with the schedule requirement, an "extension" of the original approval is granted.

INVESTIGATIONS UNDER SCHEDULE 6C

Electric cap lamps are investigated under this schedule. Virtually all of the electric cap lamps used in coal and metal mines in the United States are of permissible types; that is, lamps that have met the Bureau's schedule requirements.

General Requirements for Electric Cap Lamps

Electric cap lamps must be complete units. They must be durable in construction, practical in operation, and suitable for the conditions of underground service. They must offer no probable explosion hazard if used in gaseous or dusty mine atmospheres, nor bodily hazard from the spilling of the battery electrolyte. They must fulfill, under laboratory test conditions the various minimum performance requirements specified in this schedule. The gallery used in conducting tests in gaseous mixtures is shown in figure 2

Specific Requirements

In determining the adequacy of the lamp with respect to design, the following points are considered: (a) The materials used; (b) construction; (c) weight; (d) amount of light; (e) distribution of light; and (f) exclusion of dust from the headpiece. The suitability of the materials and the construction are determined by preliminary inspection, by dropping tests, by durability tests of the cord and cord armor, and by the general behavior of the lamp equipment during the investigation. The amount and distribution of the light are judged both by observation of the illumination on a white screen and by photometric measurements.

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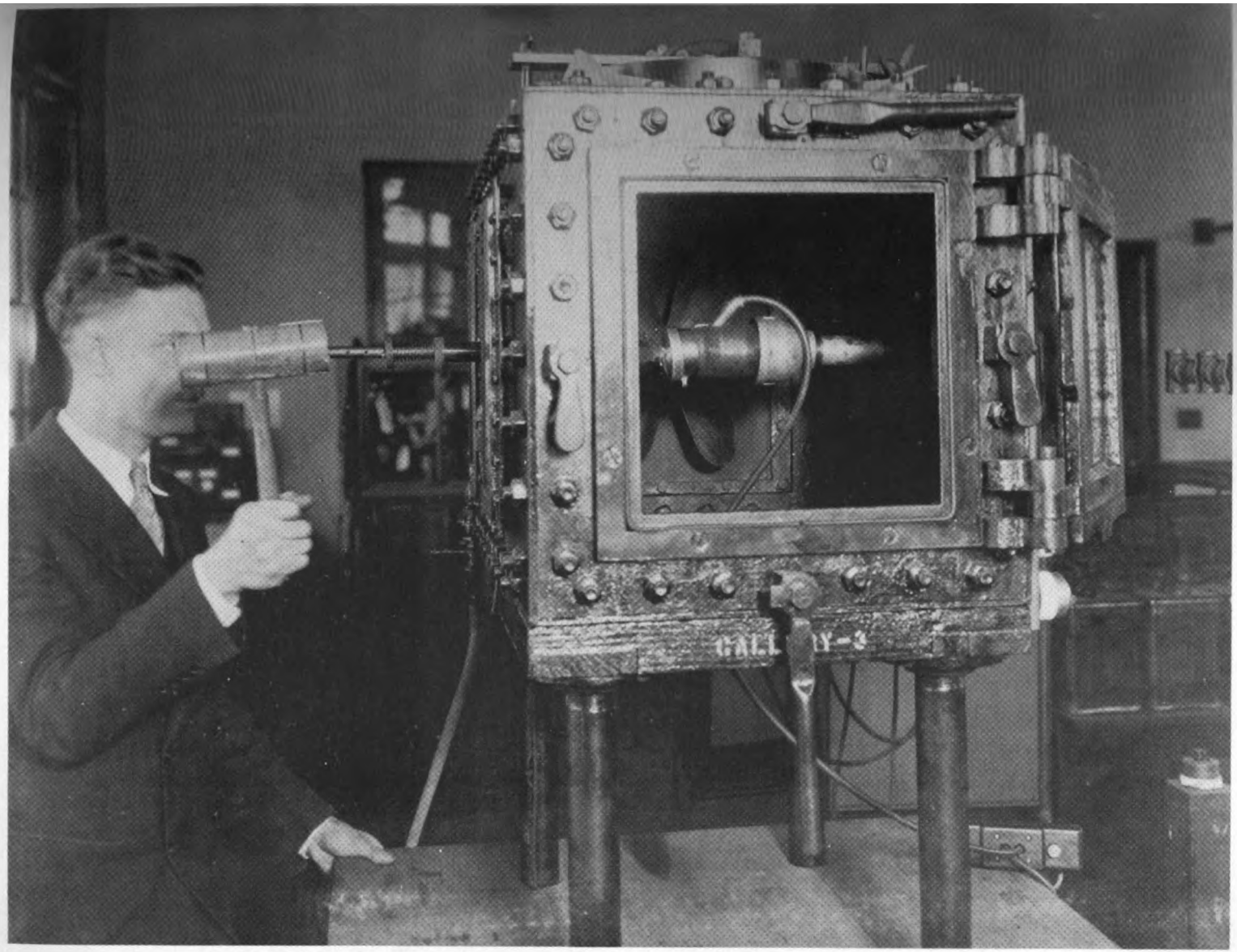

Figure 2.—Small gallery for testing electric cap lamps.

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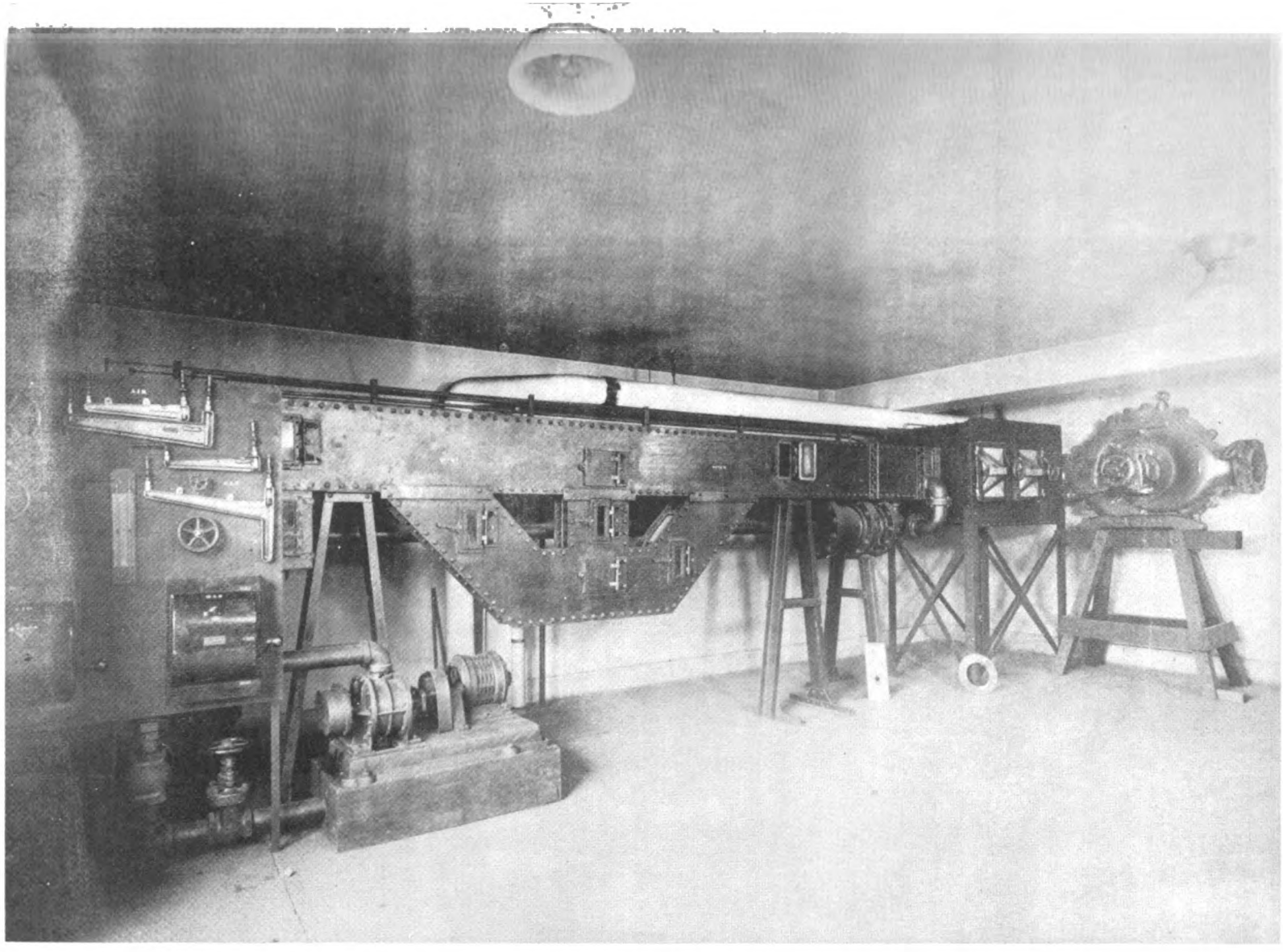

Figure 3.—Flame-lamp testing gallery.

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Angle of Light Beam

The beam or cone of light from the headpiece must have a spread of at least 130°. (Under a contemplated revised schedule this limitation may be reduced to 120°.)

Light Distribution - Visual

The surface covered by the 130 degree light beam shall not show sharply contrasting areas of bright and faint illumination.

Light Distribution, Photometric

The maximum candlepower of the 130° light beam must not be greater than five times the average or mean candlepower of the beam; the minimum candlepower of the beam, based upon readings at the design voltage of the bulb, must not be less than 1.

INVESTIGATIONS UNDER SCHEDULE 7C

The investigation of flame safety lamps under the requirements of Schedule 7C is typical of investigations that have been conducted in various countries for over a century, beginning with the first tests by Davy in 1816. Modern tests on flame safety lamps must take into consideration much higher air velocities than were experienced in the early days. Tests in air velocities of 2,500 feet per minute are made in the lamp-testing gallery shown in figure 3.

Requirements for Flame Safety Lamps

Safety in Explosive Atmospheres

General. - Lamps must be so constructed that they will not cause external ignitions when tested in gassy or dusty atmospheres, such as may be found in coal mines.

Igniter. - Special tests are made to determine the safety of the igniter device as follows:

1. To determine whether external ignition is possible when the igniter is operated within the lamp in still mixtures of Pittsburgh natural gas and air.

2. To determine whether the residue left in the lamp after working the igniter device is a source of danger in the subsequent use of the lamp.

3. To determine the composition of the sparking material.

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Construction Involving Safety, Operation, and Maintenance

General. - Lamps are examined with special reference to their mechanical construction, strength, size, and weight, the replacement of parts, the ease of inspection, and the attention required to maintain proper operation. The construction must be such that the omission or incorrect placing of any part when the lamp is assembled may be noticed readily. Provision must be made for the protection of glass chimneys against breakage by expansion or by shock.

Lock. - Lamps must be provided with a magnetic lock adequate to prevent the loosening or removal, from the locked lamp, of any part vital to safety.

Gauzes. - If gauzes are used they must be adequate for the degree of safety required. Adequacy is determined by tests in moving and still mixtures of Pittsburgh natural gas and air, and by inspection of the gauzes relative to the following:

(1) The material of which the gauzes are made.

(2) The gauze mesh.

(3) The fabrication of the gauzes, particularly as to uniformity and distortion at seams.

(4) The relative dimensions of inner and outer gauzes.

Glasses. - The suitability of the glasses is determined under the following requirements:

(1) The quality and form of the glass. The glasses must have smooth surfaces throughout and should be clear. Their ends should be parallel and at right angles to the axis of the glass.

(2) Resistance to breakage. The glasses are tested to show their resistance to mechanical blows, both alone and when assembled in the lamp, and to sudden temperature changes, such as those caused by spraying with water at a temperature 85° C. lower than that of the heated glasses.

(3) Identification. The glasses should be marked distinctly and permanently by a name or design, by which they are to be designated commercially.

(4) Protection of the glass against breakage. Standards or other means used for protection of the glass should protect the glass from breakage except under a direct blow against the glass.

Bonnet. - The lamp must be equipped with a bonnet to shield the gauze from the direct action of air currents. The adequacy of the bonnet is determined as follows:

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The completely assembled lamp is suspended as a pendulum, the point of suspension being 6 feet above the center of the bonnet. The lamp is drawn 45° from the vertical and allowed to swing freely against the edge of a rigid steel, flat bar 1/4 inch thick, the edge being vertically under the point of suspension. Inward deformation of the bonnet from its normal shape or position must not be greater than 10 percent of the original outside diameter of the lamp bonnet. The lower openings of the bonnet must not be materially distorted by this test.

Performance. - The lamp must give the following performance:

(1) It must give positive evidence of the presence of methane and of deficiency of oxygen in mine atmospheres, either through observation of the flame or by a suitable attachment, showing a definite indication in concentrations as low as 1 percent methane.

(2) It must have a free-burning, steady flame, sufficient fuel capacity to give 12 hours burning per filling with its normal flame, and a wick adjustment that is simple and dependable.

INVESTIGATIONS UNDER SCHEDULE 8C

General Requirements

Methane detectors approved under this schedule should be portable. They must be durable in construction, practical in operation, and suitable for service conditions underground. They must offer no probable explosion hazard if used in gaseous mine atmospheres or any bodily hazard, such as spilling of battery electrolyte. They must meet under laboratory test conditions the various requirements of minimum performance specified in the schedule.

Specific Requirements

• Design

In determining adequacy of design the following points are considered: a) Materials used; (b) construction; (c) accuracy; (d) size and shape; e) range of detection (or indication); (f) life of the active parts; and g) attention required. The suitability of the materials and the construction are determined by preliminary inspection, by dropping tests, by laboratory and field tests in gas and air mixtures, and by the general behavior of the equipment during the investigation.

• Safety Against Explosion Hazard

(a) Detectors must be constructed so that they will not cause external ignitions when used in gaseous mine atmospheres.

(b) Seals or locks. - All parts through which external ignitions might result must be covered and protected adequately. All covers must be sealed

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adequately or equipped with magnetic or other equally reliable locks to prevent their being opened by unauthorized persons.

(c) Glasses. - Glasses or glass windows must be of good quality glass and protected adequately against breakage. Unguarded windows are considered adequate in this respect, provided they are of small diameter and are of reasonably thick glass.

(d) Battery. - If the detector is equipped with a battery it must be of such design that it will not produce sparks that will ignite an explosive mixture of methane and air.

(e) Detectors of the flame type. - Methane detectors of the flame type are subjected to the requirements of the flame-lamp schedule in force.

3. Safety Against Bodily Hazard

Bodily hazard with battery-type detectors is due chiefly to possible burning of the user by electrolyte that has spilled from the battery. The Bureau, therefore, makes the following requirements:

(a) Spilling of electrolyte. - The battery must be so designed and constructed that, when properly filled, it will not spill electrolyte under actual service conditions.

(b) Corrosion of battery container. - The material of which the container is made must resist corrosion under conditions of use.

4. Performance

In addition to the general design and safety features, the Bureau considers that permissible types of methane detectors should meet certain minimum requirements with respect to their performance, as follows:

(a) Detectors. - When the detector is operated according to the manufacturer's instructions, it should detect as low as 1 percent and as high as 3 percent methane in air. It is recommended that if practicable the detector be designed to permit detection of concentrations of methane as high as 5 percent in air.

The average number of determinations that may be made in approximately 2-percent methane mixtures without recharging a battery or replacing a chemical accessory shall not be less than 25, and the average number of such determinations that may be made without replacing any other part must be not less than 100.

(b) Indicating detectors. - Indicating detectors must give indications of as low as 0.25 percent methane. Detectors having an upper scale limit of 2 percent may be approved, but it is recommended that the detector be designed to give indications of as high as 4 percent methane. The indications for these percentages must be within the limits of error specified in the following table:

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Allowable variations in scale reading, percent

Methane in mixtures	Minimum indication	Maximum indication
0.25	0.10	0.40
.50	.35	.65
1.00	.80	1.20
2.00	1.80	2.20
3.00	2.70	3.30
4.00	3.70	4.30

Tests are made at several percentages within the range of the indicating detector and at temperatures between the limits of 50° and 70° F., by increments of 5°. Ten determinations are made at each percentage. Neither the average of the 10 readings nor more than 2 readings for each percentage shall exceed the limits of error given in the table.

The average number of determinations that may be made with an indicating detector without replacement of any part should be not less than 30, and the average number that may be made without recharging the battery should be not less than 15.

The scale must not be subdivided into smaller divisions than the general accuracy of the indicating detector warrante.

(c) Mechanical strength. - Detectors and indicating detectors are subjected to the following mechanical tests: Four of each of those parts or groups of assembled parts that are not normally strapped to the user are dropped 20 times on a wood floor from a height of 3 feet. Parts that are strapped to the user are subjected to a jarring or bumping test to demonstrate adequate strength. The average number of times that any one of the detectors can be dropped before breakage or material distortion of essential parts must be not less than 10.

5. Attachments for Illumination

If detectors are provided with attachments for illuminating purposes, such attachments are subjected to the same requirements as those applying to that type of lamp under the lamp schedule then in force.

INVESTIGATIONS UNDER SCHEDULE 9B

The present requirements for signaling devices have been made more rigid than stipulated by the former schedule, which covered telephones only, in that this schedule states that

> The circuits external to telephones and signal devices shall be intrinsically safe; that is, the electrical design and construction of telephones and signal devices shall be such that neither

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contact between wires comprising the external circuits nor contact of tools or other metal objects with external terminals and circuits will result in electrical sparks capable of igniting explosive methane-air mixtures (or such mixtures with coal dust in suspension) during normal operation of the telephones or signal devices.

2. All parts which, during normal operation, are capable of producing sparks that might ignite explosive methane-air mixtures, shall be enclosed in explosion-proof compartments. All openings in the casings of such compartments shall be adequately protected. It is desirable that openings be as few as possible. All joints in the casing of an explosion-proof compartment shall be metal-to-metal so designed as to have a width of contact, measured along the shortest path from the inside to the outside of the compartment, of not less than 1 inch if the unoccupied volume (air space) in the compartment is more than 60 cubic inches. For unoccupied volumes of 60 cubic inches or less, a 3/4-inch width of contact will be acceptable.

3. All bolts and screw holes shall be 'blind' or bottomed if the omission of a bolt or screw would otherwise leave an opening into the compartment. An adequate lock or seal shall be provided to prevent tampering and exposure of spark-producing parts by unauthorized persons.

4. Battery cells shall be placed in an explosion-proof compartment or else in one that is locked or sealed, and the terminals and the connections thereto shall be so arranged and protected as to preclude meddling, tampering, or making other electrical connections with them.

5. Manufacturers shall furnish adequate instructions for the installation and connection of telephones and signal devices in order that the safety of these devices and their circuits shall not be diminished by improper installation. The Bureau reserves the right to require the attachment of wiring diagrams to the cases of telephones and signal devices.

6. If electric light bulbs are used in signaling devices, they shall either be equipped with effective safety devices, (such as are required for permissible electric mine lamps) or shall be enclosed in explosion-proof compartments.

The former schedule safeguarded the phones but did not include safety requirements for all circuits coming to or leading from the apparatus. As yet, no equipment has been approved under this schedule.

INVESTIGATIONS UNDER SCHEDULE 10C

All types of portable electric lamps other than electric cap lamps are investigated under this schedule. The safety tests are identical in

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principle with those made for electric cap lamps. Hand lamps, signal lamps, inspection lamps, pneumatic electric lamps, storage battery type floodlamps, flashlights, lanterns, and lamps for use on mules in haulage service have been investigated and are on the Bureau's list of approved lamps.

INVESTIGATIONS UNDER SCHEDULES 12B AND 16A

These schedules cover shot-blasting units of single-shot and multiple-shot type, respectively.

Single-shot blasting units approved under Schedule 12B must be practical in construction and operation and suitable for service conditions underground. They must offer no probable explosion hazard when used in gassy mine atmospheres. They must meet, under laboratory test conditions, the following requirements of minimum performance:

1. The unit must fire consistently single electric blasting caps through a total resistance of 4-1/2 ohms.

2. The unit must not produce sparks capable of igniting explosive mixtures of methane and air.

3. Battery units approved under this schedule must be of the dry-cell type; they must not have directly exposed terminals. The terminals may be of the recessed type, provided they are placed on a side or end of the unit, and the depth, shape, and position of the recesses are such as to guard against accidental contact and to insure disconnection of the battery from the leading wires as soon as the contactors are released by the operator.

Recommended dimensions for the recesses are as follows: Depth, 1/2-inch; diameter at bottom, 1/16 to 1/8-inch; diameter at entrance, 1/8 to 3/16-inch; distance between centers of recesses, 1-1/8 to 1-1/4 inches (the last dimensions are stated for the purposes of uniformity among units).

4. The short-circuit current of the battery must not exceed 10 amperes.

5. Magneto units must be operable only by a special key or handle. The design and position of the socket shall be such that the key will drop or be propelled from the socket as soon as released by the operator.

6. A unit that depends on some special modification, such as a shunt resistance, to prevent igniting sparks, must have its housing sealed or locked to prevent removal or disturbance of this safety feature.

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Requirements for Multiple-Shot Blasting Units

General Requirements

Multiple-shot blasting units approved under Schedule 16A must be portable. They must be durable in construction, practical in operation, and suitable for service conditions underground. They must offer no probable explosion hazard when used in gaseous mine atmospheres. They must meet under laboratory test conditions the various requirements of minimum performance that are specified in the schedule.

Specific Requirements

All Types. - In the determination of adequacy of design, the following points are considered: (a) Materials used; (b) construction; (c) size and shape; (d) life of the active parts; and (e) attention required. The suitability of the materials and the construction are determined by preliminary inspection, by dropping tests, and by the general performances of the unit during the investigation.

The manufacturer's name plate must show the rating of the unit, the method of connecting the electric blasting caps, the kind and maximum length of leg wires that may be used and the proper method of operating the unit.

Units of the Battery Type. - 1. The units must fire 10 electric blasting caps in series through a total resistance of 25 ohms.

2. The battery must be so designed or limited in output that it will not cause ignition of an explosive mixture of methane and air.

Note: Sparking tests relative to this requirement are made with a brush-type contactor of approximately 50 No. 34 copper wires. The contactor is surrounded by an explosive mixture of Pittsburgh natural gas and air. The tests consist of making and breaking the discharge of each of three units at least 300 times with the contactor operating about 60 times per minute. The resistance of the contactor circuit must not be greater than 0.25 ohm.

3. The battery must be enclosed in a waterproofed housing and must not have directly exposed terminals. The terminals may be of the recessed type, provided the depth, shape, and position of the recesses are such as to guard against accidental contact and to insure disconnection of the battery from the leading wires as soon as the contactors are released by the operator. In this respect, it is recommended that the recesses be at least 1/2-inch deep, with a small bellmouth-type opening, and be placed at a side or end of the unit.

Units of the Generator Type. - 1. The units must fire 10 electric blasting caps in series through a total resistance of 50 ohms.

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2. Generator units must be equipped with an automatic switch device so designed that connection to the firing circuit is not made until the end of the operation stroke and is reopened 5 milliseconds ±20 percent thereafter.

3. The design of the unit must insure that the switch will not connect to the firing circuit, except by approximately full stroke of the operating handle.

4. The unit must be operated by means of a special key or handle which when released by the hand will be automatically returned to its original position.

5. Provision must be made for sealing or locking the housing of the unit to prevent unauthorized tampering with or disturbance of the timing switch setting.

CONCLUSION

In preparing these schedules the Bureau works with the manufacturers of equipment and with the users to the end that the requirements shall not be unnecessarily burdensome to the mining industry. It is believed that the use of apparatus and equipment that have been investigated and approved under these schedules adds materially to the safety of gassy and dusty coal mines and that without such an approval system, there would be an increase of mine explosions with the usual attendant loss of life.

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